MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2018/2019

EEL2216 – CONTROL THEORY
(All sections / Groups)

22 OCTOBER 2018
9.00 a.m. – 11.00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of **SIX** pages including cover page with **FOUR** questions only.

2. Answer **ALL** questions and print all your answers in the answer booklet provided.

3. All questions carry equal marks and the distribution of the marks for each question is given. The table of Laplace Transform Pairs is given in the Appendix.

Question 1

(a) A system is described by the differential equation as given by:

$$2\frac{d^2}{dt^2}y(t)+14\frac{d}{dt}y(t)+24y(t)=2\frac{d}{dt}x(t)+4x(t)$$

where $x(t)$ and $y(t)$ are the input and output of the system, respectively. Assuming zero initial conditions, do the following:

(i) Find the system transfer function $H(s)$. [3 marks]

(ii) Find the response of $y(t)$, given that $x(t)$ is a unit step function. [8 marks]

(b) Using Laplace transform, write the modeling equations for the two-mass mechanical system shown in Figure Q1(b). Note that $f(t)$ is the applied force. [4 marks]

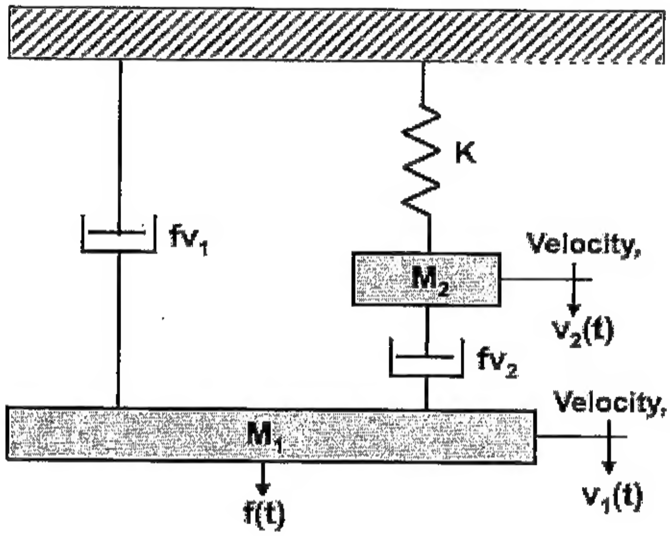

Figure Q1(b)

(c) Using Mason's rule, obtain a single transfer function $T(s) = C(s)/R(s)$ for the signal flow graph shown in Figure Q1(c). [10 marks]

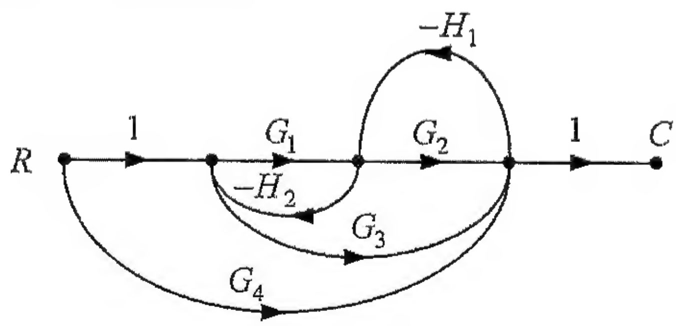

Figure Q1(c)

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Question 2

Figure Q2 shows the control system of an industrial plant.

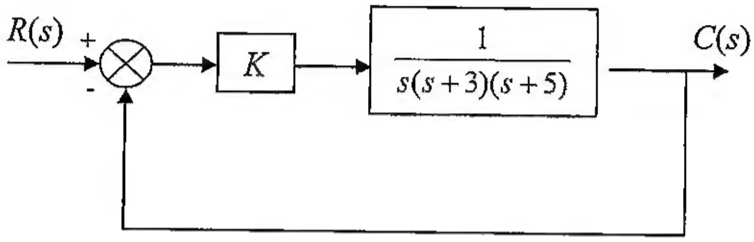

Figure Q2

(a) Evaluate the static error constants and determine the steady-state error for the unit step, ramp, and parabolic inputs. [6 marks]

(b) Determine the following:

(i) The starting and ending points. [2 marks]

(ii) Behaviour at infinity. [3 marks]

(iii) Root loci on the real axis. [1 mark]

(iv) Intersection with imaginary axis. [5 marks]

(v) Break-away point. [4 marks]

(vi) Based on your answers in (i) to (v), sketch the root locus. Show all the critical points. [4 marks]

Question 3

(a) Explain briefly the Nyquist stability criterion. [3 marks]

(b) A system has the following transfer function:

$$G(s)=\frac{64}{(s+4)^2}$$

(i) Calculate the magnitude and phase of the system at $\omega = 0$ rad/s, 4 rad/s and ∞. [4 marks]

(ii) Sketch the polar plot for this system. [3 marks]

(iii) Resketch the polar plot if one of the poles is removed. [6 marks]

(c) Consider the following transfer function:

$$G(s)=\frac{5(s+1)}{s(s+3)}.$$

List out all the basic factors and their corresponding corner frequencies and magnitudes/slopes. [9 marks]

Continued...

Question 4

(a) A controller/compensator is an additional component or circuit that is inserted into a control system to compensate for a deficient performance.

(i) State the main function of Proportional Integral (PI) controller, Proportional Derivative (PD) controller and Lag-Lead controller. [4 marks]

(ii) Highlight one advantage and one disadvantage of ideal compensator over non-ideal compensator. [2 marks]

(b) The unity feedback system shown in Figure Q4(b) has a controller $G_C(s)$ and a plant transfer function $G(s)$ given by:

$$G(s) = \frac{5}{(s+3)(s+7)}$$

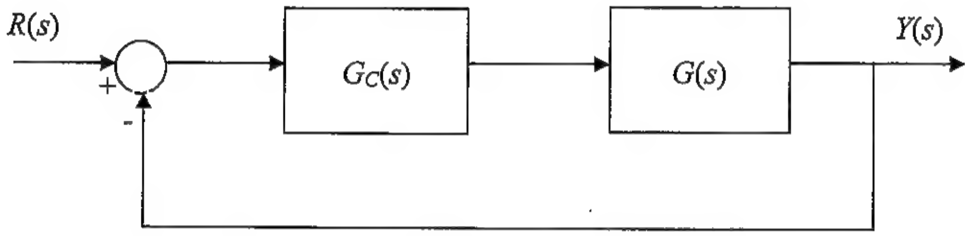

Figure Q4(b)

(i) Design a Proportional Integral (PI) controller, $G_C(s) = K_P + \frac{K_I}{s}$ such that it meets the following specificatons:

- The steady-state error is no more than 5% for a unit ramp input
- The system is stable (or on the boundary of stability)

[15 marks]

(ii) If the zero of the PI controller is set at $s = -5$, and both the proportional constant and integral constant are as obtained in part (i), is the closed loop system stable? Justify your answer. [4 marks]

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Appendix - Laplace Transform Pairs

$f(t)$	$F(s)$
Unit impulse $\delta(t)$	1
Unit step $1(t)$	$\frac{1}{s}$
t	$\frac{1}{s^2}$
$\frac{t^{n-1}}{(n-1)!} \quad (n = 1, 2, 3, \ldots)$	$\frac{1}{s^n}$
$t^n \quad (n = 1, 2, 3, \ldots)$	$\frac{n!}{s^{n+1}}$
e^{-at}	$\frac{1}{s+a}$
te^{-at}	$\frac{1}{(s+a)^2}$
$\frac{t^{n-1}}{(n-1)!}e^{-at} \quad (n = 1, 2, 3, \ldots)$	$\frac{1}{(s+a)^n}$
$t^n e^{-at} \quad (n = 1, 2, 3, \ldots)$	$\frac{n!}{(s+a)^{n+1}}$
$\sin \omega t$	$\frac{\omega}{s^2+\omega^2}$
$\cos \omega t$	$\frac{s}{s^2+\omega^2}$
$\sinh \omega t$	$\frac{\omega}{s^2-\omega^2}$
$\cosh \omega t$	$\frac{s}{s^2-\omega^2}$
$\frac{1}{a}(1-e^{-at})$	$\frac{1}{s(s+a)}$
$\frac{1}{b-a}(e^{-at}-e^{-bt})$	$\frac{1}{(s+a)(s+b)}$
$\frac{1}{b-a}(be^{-bt}-ae^{-at})$	$\frac{s}{(s+a)(s+b)}$
$\frac{1}{ab}\left[1+\frac{1}{a-b}(be^{-at}-ae^{-bt})\right]$	$\frac{1}{s(s+a)(s+b)}$

Continued...

Appendix - Laplace Transform Pairs (continued)

$\frac{1}{a^2}(1-e^{-at}-ate^{-at})$	$\frac{1}{s(s+a)^2}$
$\frac{1}{a^2}(at-1+e^{-at})$	$\frac{1}{s^2(s+a)}$
$e^{-at}\sin\omega t$	$\frac{\omega}{(s+a)^2+\omega^2}$
$e^{-at}\cos\omega t$	$\frac{s+a}{(s+a)^2+\omega^2}$
$\frac{\omega_n}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin\omega_n\sqrt{1-\zeta^2}t$	$\frac{\omega_n^2}{s^2+2\zeta\omega_n s+\omega_n^2}$
$-\frac{1}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin(\omega_n\sqrt{1-\zeta^2}t-\phi)$ $\phi=\tan^{-1}\frac{\sqrt{1-\zeta^2}}{\zeta}$	$\frac{s}{s^2+2\zeta\omega_n s+\omega_n^2}$
$1-\frac{1}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin(\omega_n\sqrt{1-\zeta^2}t+\phi)$ $\phi=\tan^{-1}\frac{\sqrt{1-\zeta^2}}{\zeta}$	$\frac{\omega_n^2}{s(s^2+2\zeta\omega_n s+\omega_n^2)}$
$1-\cos\omega t$	$\frac{\omega^2}{s(s^2+\omega^2)}$
$\omega t-\sin\omega t$	$\frac{\omega^3}{s^2(s^2+\omega^2)}$
$\sin\omega t-\omega t\cos\omega t$	$\frac{2\omega^3}{(s^2+\omega^2)^2}$
$\frac{1}{2\omega}t\sin\omega t$	$\frac{s}{(s^2+\omega^2)^2}$
$t\cos\omega t$	$\frac{s^2-\omega^2}{(s^2+\omega^2)^2}$
$\frac{1}{\omega_2^2-\omega_1^2}(\cos\omega_1 t-\cos\omega_2 t)\quad(\omega_1^2\neq\omega_2^2)$	$\frac{s}{(s^2+\omega_1^2)(s^2+\omega_2^2)}$
$\frac{1}{2\omega}(\sin\omega t+\omega t\cos\omega t)$	$\frac{s^2}{(s^2+\omega^2)^2}$

End of Paper